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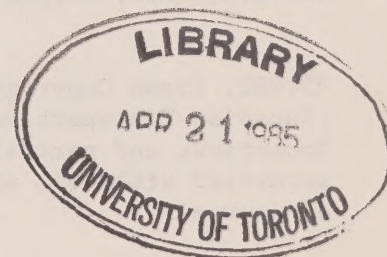
A SOCIO-ECONOMIC IMPACT ANALYSIS OF THE REGULATIONS EMANATING FROM THE RTC SHOW CAUSE HEARING DECISION ON RAILWAY SAFETY

Canada

A SOCIO-ECONOMIC IMPACT ANALYSIS
OF THE REGULATIONS EMANATING FROM THE
R.T.C. SHOW CAUSE HEARING DECISION ON RAILWAY SAFETY

prepared by

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CANADIAN TRANSPORT COMMISSION
Railway Transport Committee
April 8, 1982


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1.0 INTRODUCTION

1.1 Regulatory Mandate

The Canadian Transport Commission's power to make orders and regulations is defined in section 46 of the National Transportation Act. With respect to rail transport, this power is more explicitly defined in sections 227 and 296 of the Railway Act. Reference is made to section 227(1)(1) which reads as follows:

The Commission may make orders and regulations (...) generally providing for the protection of property, and the protection, safety, accommodation and comfort of the public, and of the employees of the company, in the running and operating of trains and the speed thereof, or the use of engines, by the company on or in connection with the railway.

Section 296(1) states:

The company shall not carry any goods of an explosive or dangerous nature except in conformity with the regulations made by the Commission in that behalf.

It is under this legislative umbrella that the regulations emanating from the C.T.C. "Show Cause" Hearing Decision on Railway Safety will issue.

1.2 Statement of Purpose

The Cabinet policy on socio-economic impact analysis (S.E.I.A.) of health, safety and fairness (H.S.F.) regulations has been in effect since August 1, 1978. The policy requires that major new H.S.F. regulations be subjected to socio-economic impact analysis prior to their promulgation. This report has been prepared in accordance with the S.E.I.A. policy.

The report has been structured in order to:

- | | |
|-----------|---|
| DESCRIBE | - the problem to be addressed through regulation |
| | -- how the immediate concern arose |
| | - the nature of consultation with the private sector in the development of the regulations |
| | |
| SUMMARIZE | - the policy constraints |
| | - the analysis of proposed regulations emanating from the Mississauga Inquiry |
| | - the development of viable alternatives |
| | |
| ANALYZE | - the allocative effects of proposed regulations emanating from the Show Cause Hearing Decision on Railway Safety |
| | - the non-allocative effects of proposed regulations emanating from the Show Cause Hearing Decision on Railway Safety |

The scope of the problems to be addressed through regulation is limited to bearing failure related derailments and the safety performance of equipment used to transport dangerous goods. Of immediate concern are

bearing failure related derailments of trains carrying dangerous goods. Hence, the information and analysis presented in this report are restricted accordingly.

Sections 2.0, Background, and 3.0, Analysis and Development of Alternatives, are excerpts from the "R.T.C. Show Cause Hearing Decision on Railway Safety", issued September 30, 1981 (with minor editorial changes in some places. The full text of that decision is available upon request). The remaining sections of this paper have been prepared in response to a request from the Railway Transport Committee. These latter sections constitute staff analysis and do not necessarily represent the views of the Railway Transport Committee.

2.0 BACKGROUND

2.1 The Mississauga Accident

On Saturday, November 10, 1979, just before midnight, a CP Rail freight train derailed at Mavis Road in the City of Mississauga, Ontario. Of the twenty-four cars that derailed, twenty-one were tank cars and nineteen carried dangerous commodities (chlorine, propane, toluene and caustic soda). The first derailed car was a tank car carrying toluene. Fire ensued and three cars carrying propane exploded and caused considerable damage to neighbouring property. Chlorine was released from one tank car, and due to the fear of the consequences of that release, almost a quarter of a million people were evacuated from their homes and businesses for periods of up to six days.

Within a few hours following the derailment, the immediate cause of the accident was known to the railway and to the Canadian Transport Commission's staff. Clear evidence existed at the scene that a plain bearing on the toluene tank car had over-heated (in other words, had developed a "hot box") and had burnt-off resulting in the derailment.

Journal burn-offs are caused by over-heating of the bearings. The almost universal cause of the over-heating of a plain bearing is the lack of lubrication of its components. Over-heating can arise for a number of reasons including improper maintenance or inadequate inspection. Nevertheless, even with the substantial effort made since the incident, no one has been able to prove specifically what brought about

the failure of the plain bearing which caused the derailment at Mississauga.

2.2 The Mississauga Inquiry

Immediately after learning of the derailment the Railway Transport Committee (RTC) decided to convene, commencing December 4, 1979, a public hearing at Mississauga, Ontario to inquire into the derailment and the results thereof. This intention was made public by the RTC three days later. In the meantime, public demands were made on the then Minister of Transport, the Honourable Don Mazankowski, for the convening of an independent inquiry, outside the Canadian Transport Commission, into the same occurrence. On December 4, 1979, the Minister of Transport announced the appointment of Mr. Justice Samuel G.M. Grange of the Supreme Court of Ontario (hereinafter referred to as Grange J.) to conduct the necessary inquiry. The basic terms of reference of that inquiry included the requirement to report on the contributing factors and causes of the derailment at Mississauga and the steps which can be reasonably taken to reduce the risk of recurrence of such an accident anywhere in Canada.

The Grange Inquiry commenced on February 4, 1980 and the hearing of evidence and argument ended some eight months later, after 23,594 pages of testimony were heard and 687 exhibits were received. The bulk of the evidence consisted of an account of events leading up to the accident, the accident itself, the post-accident activities and the regulatory system which applies to railway operations.

Grange J. submitted his "Report of the Mississauga Railway Accident Inquiry" (the Grange Report) to the Honourable Jean-Luc Pepin, Minister of Transport and on January 19, 1981, it was tabled in the House of Commons. The report contained fifteen recommendations for the technical improvement of railway safety. These recommendations were made without hearing detailed evidence related to the economic aspects of safety measures and hence without in-depth consideration of the economic impact of their implementation. In this regard, Grange J. stated in his report: "...there is a limitation that my consideration and the Report are substantially restricted to the lessons of Mississauga."

The first three recommendations of the Grange Report dealt with: a) roller bearings and the nature of equipment forming a train carrying dangerous goods; b) hot box protection; and c) dangerous goods train speed and length restrictions. These recommendations were linked in the Grange Report by making the third recommendation an option in case either the first or second recommendation could not be fully implemented. They were clearly major and were further singled out by Grange J. for immediate implementation, an urgency not given to the other twelve recommendations.

2.3 The " Show Cause" Hearing

One week after the Grange Report was tabled in the House of Commons, the Railway Transport Committee issued an Order to all railways under its jurisdiction in response to the urgency stressed by Grange J. The Order addressed the issues raised in his first three recommendations.

Twenty-three railways were ordered to "show cause" on or before February 9, 1981, why the RTC should not, effective February 12, 1981, order that:

"1. If a train transporting any commodities regulated under the Regulations for the Transportation of Dangerous Commodities by Rail (hereinafter called the "Red Book") has:

- (a) any cars in it without roller bearings;
- (b) any tank cars carrying any commodity regulated under the Red Book that does not have double shelf couplers;
- (c) any specification 112 or 114 tank cars carrying any commodity regulated under the Red Book that does not have head shields and thermal protection; or
- (d) any 111 or 114 tank cars carrying any commodity regulated by the Red Book which have bottom fittings without bottom fitting protection;

the train shall not exceed 4,000 feet in length.

2. If a train transporting any commodity regulated under the Red Book meets any of conditions (a) to (d) specified in clause 1, the train shall not exceed twenty-five miles per hour while passing through any centre of population containing 500 or more people in proximity to the track.

3. If a train transporting any commodity regulated under the Red Book:

- (a) passes through a centre of population containing 500 or more people in proximity to the track; and
- (b) the track through such centre of population does not have hot box and dragging equipment detectors installed at least every twenty miles,

the train shall not exceed twenty-five miles per hour while passing through the centre of population."

In response to the "Show Cause" Order, the RTC received many detailed submissions containing evidence and argument against placing this Order into effect on the given date. The "Show Cause" Order was opposed in numerous railway submissions and also in submissions made by many non-railway intervenors who claimed that they would be adversely affected. In consideration of the substantial concern shown and numerous arguments raised, the RTC decided to hold an open hearing in which all parties could present evidence and argument regarding implementation of the "Show Cause" Order.

The "Show Cause" Hearing took place over 31 sitting days between April 21, 1981 and July 1, 1981. During the Hearing, 5,063 pages of transcript were generated. Sixty-one persons representing 39 organizations appeared at the hearings and elicited evidence from 65 witnesses, in the process presenting 168 exhibits. As well, submissions were made in response to the original "Show Cause" Order which formed part of the basis of evidence for the Decision released September 30, 1981. These earlier submissions were made available to the public prior to commencement of the Hearing; transcripts of the Hearing itself and copies of the exhibits presented are on the public record at the Commission offices.

3.0 ANALYSIS AND DEVELOPMENT OF ALTERNATIVES

3.1 The National Transportation Act

The Railway Transport Committee, like other Committees of the Commission, is bound by the policy directives set out in section 3 of the National Transportation Act. Included in the prescribed policy is the notion that in carrying out its statutory duty the Railway Transport Committee should foster competition at least where such competition is economically feasible. In imposing safety programs on the railways under its jurisdiction, the Committee must therefore have regard to their probable cost and its effect on the competitive position of the railways vis-à-vis other modes of transportation.

3.2 A Special Dangerous Commodities List

The Red Book classifies over 3,000 commodities as dangerous, and regulates the packaging, documentation and handling of such commodities. However, not all these commodities are classified as dangerous in the sense that they pose a potential high degree of danger to the general public in the event of a railway accident.

There were representations by a number of parties at the RTC "Show Cause" Hearing to the effect that any new regulations arising from the Hearing in relation to train handling should be applicable only to commodities that present a significant risk to the public in the event of a release during or after a railway accident. The Panel agreed with this view.

A list had been prepared by Railway Transport Committee staff prior to the Mississauga accident. The list contains the commodities, which, in the opinion of the RTC staff, pose the greatest degree of danger to the public in the event of release. This Special Dangerous Commodity List was adopted. (See Appendix 1.)

3.3 The Grange Report - Recommendation One

"(a) all cars whether dangerous goods cars or not should have roller bearings;"

Generally speaking, roller bearings can be safer bearings in terms of probability of burn-offs in the context of the average maintenance and inspection program of the average North American railway. However, the Panel concluded that Grange Recommendation One (a) could not be implemented immediately because of limited shop and material availability. Furthermore, a considerable number of cars enter Canada from the United States in interchange each year and the Panel concluded that it would be impossible, from a practical point of view, to make regulations that would refuse U.S. plain bearing cars access to Canada.

The roller bearing component of the North American fleet, however, is substantially higher than that in the fleet owned or leased by Canadian-based railways. The Panel was therefore convinced that the Canadian railways should immediately accelerate their programs of change-over to roller bearings to bring the Canadian railway owned or leased fleet to the same proportion of roller bearing cars as in the North American fleet. The Canadian railways are to achieve this level by year end 1987.

"(b) all tank cars should have double shelf couplers;"

The evidence is clear that double shelf couplers are very worthwhile safety features for tank cars carrying dangerous commodities. They act to prevent or deter unintentional uncoupling of tank cars during train operations and accidents with the resultant punctures in the heads of adjoining tank cars. This type of puncture is one of the most prevalent causes of lading loss in derailment situations involving tank cars. By preventing uncoupling, double shelf couplers significantly reduce the risk of lading loss in most accident circumstances.

Pursuant to CTC General Order 1979-1 Rail dated January 22, 1979, all Specification 112 and 114 tank cars have been required to be equipped with double shelf couplers since March 31, 1979. Furthermore, all new tank cars built in the last three years have been equipped with double shelf couplers, as standard practice. There are still Specification 105, 103 and 111 tank cars built before that time which are transporting dangerous commodities without the benefit of double shelf couplers. However, the bulk of the products which pose the most danger to the public are carried in Specification 112, 114 and 105 cars. For this reason, a priority was placed on equipping 105 cars with double shelf couplers. Railways will therefore be directed not to accept for transport after June 30, 1982, any Specification 105 car which is carrying a regulated commodity and is not equipped with double shelf couplers. The same directive will apply to acceptance of 103, 111 and other CTC Specification tank cars carrying the generally less dangerous regulated products after February 28, 1985. Effective immediately, all new tank cars should be equipped with double shelf couplers.

"(c) all 112 and 114 tank cars should have head shields and thermal protection;"

CTC General Order 1979-1 required that all Specification 112 and 114 tank cars be equipped with a tank head puncture resistance system (i.e., head shields) and that all such cars carrying flammable gases be equipped with a thermal protection system. This retrofit program was completed by June 30, 1981.

During the "Show Cause" Hearing, it was indicated that, although up to this time there has not been an accident problem with 112 and 114 tank cars carrying products such as anhydrous ammonia and fluorocarbons which would have been alleviated by thermal protection, it was possible for tank cars carrying such products to violently rupture. A violent rupture involving such products could well prove disastrous for an even larger area than a violent rupture of a tank car carrying liquefied petroleum gas. The Panel has thus concluded that all remaining 112 and 114 tank cars should be retrofitted with thermal protection. This should be completed by December 31, 1982.

Presently, both full and half-head shields satisfy the requirements of the tank head puncture resistance system as prescribed by General Order 1979-1 Rail. The number of punctures has dropped considerably with the introduction of head shield protection and double shelf couplers. However, at least one puncture has occurred in the last few years above the line of a half-head shield. This is not sufficient evidence to justify changing the head shields on existing cars. However,

it is the Panel's view that new cars and any further retrofitting should utilize the full rather than half-head shield protection system.

Although the Grange recommendations in this area dealt only with 112 and 114 tank cars, the Hearing Panel also heard evidence related to 105 cars, which carry many of the same kinds of products as the 112 and 114 tank cars. There are a number of different types of 105 cars and the degree of protection varies with the purpose for which the cars are designed. Some 105 cars already possess the equivalent of the tank head puncture resistance and thermal protection present on retrofitted 112 and 114 tank cars, but others do not.

The Panel has, accordingly, decided that all new 105 cars, constructed after December 31, 1981, with the exception of those built to a service pressure of 500 or more psi, shall be equipped with a tank head puncture resistance system equivalent to that now required for 112 and 114 tank cars (i.e., a full head shield). All 105 cars constructed after December 31, 1981 shall also be equipped with thermal protection equivalent to the present requirement for 112 and 114 tank cars. Some 105 cars already meet that requirement by virtue of the design specifications of the car, but tank car manufacturers will have to ensure that all new 105 cars meet these thermal protection standards.

"(d) all 111 and 114 tank cars which have bottom fittings should have bottom fitting protection;"

Some tank cars have bottom outlets. When such outlets are not recessed into the tank and are not otherwise protected (e.g. by skid

plates), there is a great risk of the bottom outlet being sheared off in a derailment and the product consequently being spilled.

This problem has been recognized previously by the Railway Transport Committee in relation to the unit train sulphuric acid cars. These cars were required to be retrofitted with bottom outlet protection a number of years ago.

The Association of American Railroads (A.A.R.) has also been concerned about this problem and has required retrofit of some cars depending on the danger (both to human beings and to the environment) and the volume of the product being carried. This Association has examined not only bottom outlets but also other bottom discontinuities, such as sumps and washouts. The A.A.R. retrofit schedule is presently under review by that organization.

The Committee is satisfied that progress is being made in this area through the A.A.R. program. However, the Committee is not satisfied to leave this matter completely to industry action. Therefore, the Panel has decided that all new cars equipped with bottom outlets or bottom discontinuities, built after December 31, 1981, shall have such outlets protected or recessed below the surface of the tank shell.

With regard to existing tank cars, the Dangerous Commodity Technical Review Committee has been directed to prepare a recommended retrofit schedule for cars carrying products on the Special Dangerous Commodity List and submit it to the Railway Transport Committee. The

Dangerous Commodity Technical Review Committee has also been directed to prepare a recommended retrofit schedule for other cars carrying dangerous commodities and submit it by June 1, 1982.

3.4 The Grange Report - Recommendation Two

"Subject to Recommendation Three, the routes of any trains carrying dangerous goods through built-up areas should be protected by hot box detectors. No point within the built-up area should be more than 20 miles from hot box detector protection."

Grange J. said with regard to what constitutes a "built-up area", "...I have in mind any concentrated centre of population in the proximity of the track containing 500 or more people."

Canadian railways have proceeded with their hot box detector installation programs using a spacing which is comparable with the spacing used by other railways in North America. The spacing of between 25 and 30 miles was essentially based on the time which a plain bearing takes to burn-off after initial over-heating takes place. It therefore appears that the spacing is adequate insofar as it relates to plain bearings. Unfortunately, the matter is not so clear when the characteristics of roller bearings are taken into account. Roller bearings may burn-off more quickly than plain bearings once malfunctioning of the bearing commences. In fact, the statistics for the last two years suggest that a roller bearing may burn-off very quickly, over substantially shorter distances than those dictated by the chosen spacing criterion. There is not sufficient evidence available at this time to arrive at any firm

conclusion on this matter, but at least a possibility exists that a hot box detector program based on spacings of 25 to 30 miles may be inadequate to detect overheating of roller bearings. In fact, even the 20 mile separation suggested by Grange J. may be inadequate.

The Panel is not satisfied that it has sufficient grounds to justify ordering the spacing of hot box detectors closer than 20 miles apart in, or about, population centres having 500 or more people in proximity to the track. Certainly no party at the "Show Cause" Hearing supported that population criterion. As well, considering the capital cost of over \$100,000 per installation, the economic impact of such a massive hot box detector program would be extremely burdensome.

In regard to hot box detector spacing, however, the Panel considers it vital that reliable information be obtained of the actual times taken for a roller bearing to burn-off under different conditions. The Panel has therefore referred this requirement for study to the Technical Research Committee of Strategic Planning, Transport Canada for action. The RTC will monitor carefully on an on-going basis all hot box and burn-off occurrences. Results of both of these efforts will serve to determine if a future reduction in the existing general hot box detector spacing standard is required.

There is ample evidence to conclude that massive additions of hot box detectors to Canadian railway systems cannot be accomplished overnight. There are limits to the availability of detectors and to the ability to install them. Priority guidelines are first required before

considering what is necessary to obtain adequate system-wide hot box detector protection. In this regard, the difficulty of evacuation of an area adjacent to the track is an important factor and should be given priority consideration.

The Panel recognizes that traffic volume and dangerous commodity traffic volume are also reasonable factors to set priorities of installation. Nevertheless, the Panel concludes that population should be the primary factor governing the priority of future installation programs.

Protection of Metropolitan Areas

In Canada, there are 24 census metropolitan areas which are traversed by railways and which house in excess of 100,000 people (see Appendix 1). Of utmost urgency is the assurance that these areas are protected in accordance with the attendant risks of high population density centers. The Panel therefore ordered the railways to adopt a twenty-mile hot box detector spacing criterion for use on railway lines within those metropolitan areas which carry special dangerous commodities. The Panel further ordered the immediate commencement of an installation program to meet this criterion with the program to be fully implemented by March 1, 1982. As an alternative to the installation of hot box detectors, mechanical inspections by railway personnel may be substituted if performed at similar intervals. In either case, measurement for spacing purposes is to begin at the point of gateway inspection.

Gateway Inspections

The Panel also believes and therefore ordered effective March 1, 1982 that all trains carrying any special dangerous commodity should be subjected to a "gateway" inspection before proceeding into a metropolitan area. The location of the inspection should be no further than 20 miles from the boundaries of the metropolitan area and no closer than 3 miles thereto.

Such gateway inspection need not necessarily be performed physically by railway employees but rather it might be accomplished by the use of available technology in the form of trackside scanners designed to detect hot wheels, over-heated journal bearings, dragging equipment, extra dimensional loads or other unsafe conditions which are capable of being automatically detected.

The Committee ordered that the above requirements for hot box protection within metropolitan areas could be waived where trains carrying special dangerous commodities are operated at less than 15 m.p.h.

The gateway inspection principle outlined above should be expanded on by the railways, phasing in similar protection for less densely populated areas in the coming years. In this respect, the Committee ordered that all areas with a population between 50,000 and 100,000 be so protected by October 1, 1984 and those with a population between 10,000 and 50,000 be so protected by October 1, 1987. (See Appendix 1.)

3.5 The Grange Report - Recommendation Three

"If a dangerous goods train does not comply with Recommendation One, it should not exceed 4,000 feet in length regardless of the hot box detector protection provided.

If the dangerous goods train does not comply with Recommendation One, or if the route of the dangerous goods train passing through a built-up area does not comply with Recommendation Two, the train passing through the built-up area should not exceed 25 miles per hour."

Train Length Restriction

Not one party at the "Show Cause" Hearing supported the implementation of train length restrictions to 4,000 feet. When visibility is good and when the nature of the track allows train crews to inspect trains en route, shortening the length of dangerous goods trains would facilitate en route inspection by the front and rear end crews thereby improving the safety of train operations through earlier detection of hazardous conditions. In many areas, however, the nature of the track makes this type of inspection difficult. Also, in some weather conditions this type of inspection is not feasible. As against the one advantage, cited above, shortening the length of the trains will increase the number of trains and that by itself may increase the risk of additional accidents. Increasing the number of trains will increase the use of level crossings by trains and hence can be expected to increase the number of level crossing accidents. Reducing the length of trains would have a substantial effect upon the economic operation of the railways. Additional crews, motive power and rolling stock would be required.

Furthermore, in areas where the rail lines are already being used at or near capacity, additional infrastructure would be required.

The Panel has no hesitation in finding that this recommendation has no overall safety advantage, and that it will result in an increased risk to the public. This, coupled with the significant cost implications, leads the Panel to conclude that the recommendation for limiting the length of trains carrying dangerous commodities should not be implemented.

Train Speed Restriction

The 25 m.p.h. speed limit and the applicable implementation criteria suggested by Grange J. do not appear to the Panel to have been based upon scientific studies or data. However, the Panel has no difficulty in accepting that, in the event of a derailment, the probability of tank car rupture is greater at higher speeds.

The evidence presented by the railways offers a number of reasons to be concerned about the 25 m.p.h. figure, as well as the technical safety implications of operating trains at less than track speed and of accelerating and decelerating trains to meet the limit in certain track areas. The evidence adduced also indicated that the recommended speed reduction would have a substantial effect on transportation efficiency, crew, rolling stock and power capacity and other factors which would result in large increases in operating expense and sizeable reductions in certain main line track capacity.

Generally speaking, railways set train speed limits which are related to the design of their track. The superelevation of a curve, for instance, is designed for a certain train speed. Lower train speeds over such a curve cause increased hazard of derailment and increased track maintenance costs. Posted speed limits may, however, be less than track design speed for a variety of reasons. The number of train speed changes are normally limited to reduce the frequency of "buff and slack" forces associated with train acceleration and deceleration. These forces can cause knuckle and draw bar failure which can result in derailment. For these reasons, therefore, implementation of speed limits well below track design speed and in numerous locations may increase the frequency of derailments.

The railways also argued that the 25 m.p.h. limit was sufficiently close to that speed at which the phenomenon referred to as harmonic oscillation is observed and that chances of derailment would be increased in areas where the speed limit was imposed. The harmonic oscillation of railway cars occurs when the center to center spacing of trucks is the same as the length of 39 foot jointed rail and when the cars travel over that rail at speeds ranging from 10 to 25 m.p.h. This phenomenon is very complex. Essentially, the car begins to rock side to side on the rails and thereby becomes more prone to the chance of derailment. Even though the Panel understands that, to a large degree, this problem has been resolved and is not as prevalent as it was in the late 1960's and early 1970's, the probability of the proposed speed limit increasing this occurrence is of concern.

More specifically, the suggested speed limit is at the top end of the train speed range at which harmonic oscillation is most frequent. It could be argued that the speed limit is nonetheless warranted when this fact is weighed against the benefit of reduced chance of tank car rupture upon derailment. The trade-off is not that clear, however. Train crews attempting to achieve a speed limit of 25 m.p.h. will in practice tend to operate below that speed and at times in the speed range where this phenomenon is most prevalent. There is clearly a need to balance the negative effects of speed reduction on the chance of derailment against the positive effects of speed reduction on the risk of tank car puncture in the event of a derailment. All of this considered, the Panel concludes that the 25 m.p.h. train speed limit is too slow to yield a net positive benefit to public safety. The Panel nevertheless finds that the concept of a train speed limit in certain high hazard areas makes very sound sense.

After considering this subject matter carefully, the Panel is receptive to the suggestion that in very high population areas, the speed of trains carrying dangerous commodities should be restricted and in lower population density areas where adequate gateway inspection and hot box detector installations are not present some moderation of train speeds should be imposed.

As an immediate measure, the Committee ordered that in metropolitan areas having a population of 100,000 or more, the speeds of trains carrying special dangerous commodities should be restricted to 35 m.p.h. The Panel has chosen 35 m.p.h. in order to avoid harmonic

oscillation risk and it further appears to the Panel that there would be very little difference in the risk of puncture of dangerous commodity carrying cars between a maximum speed limit of 25 m.p.h. and one of 35 m.p.h. As well, the Panel realizes that in practice train crews attempting to achieve this limit will in all probability realize actual train speed at a lower level. From an economic point of view, the cost of such a speed limitation under these restrictive conditions is substantially below the cost incurred by the 25 m.p.h. Grange recommendation.

Pending adequate gateway inspection facilities/procedures, for areas housing 50,000 to 100,000 people the Committee also ordered that all trains carrying special dangerous commodities shall be restricted to 35 m.p.h. through those areas.

4.0 ANALYSIS OF THE ALLOCATIVE EFFECTS

4.1 General Approach

The socio-economic impact analysis of the proposed regulations emanating from the C.T.C. "Show Cause" Hearing Decision on Railway Safety is based on the application of a cost-effectiveness methodology. Data inadequacies dictated against the use of either a cost-benefit or a risk-benefit approach.

The time-horizon for the cost-effectiveness analysis is dependent upon the expected lifetime of the goods or products affected. The life of an average freight train car is longer than thirty years and is comparable to the expected life of signaling equipment. However, given the increasing uncertainty and decreasing present value weighting over time, the study horizon has been established at twenty years.

The real social discount rate used in the socio-economic impact analysis is 10%. Sensitivity analysis is performed using rates of 5% and 15%. These social discount rates have been specified by the Technical Advisory Group on Impact Assessment of the Treasury Board Secretariat.

The calculation of the costs to be incurred and the discussion of the benefits to be accrued are presented separately for each of the proposed regulations. Cost-effectiveness ratios are developed for the roller bearing retrofit program. Finally, costs are summarized and the results of the sensitivity analysis are tabulated.

4.2 Assumptions

1. Calculations of social costs and benefits resulting from the accelerated conversion of the Canadian railway revenue car fleet from plain bearing to roller bearing equipment assume no change in fleet size. This is a conservative assumption. To the extent that growth in fleet size materializes, the cost impact of the C.T.C. decision would be decreased given that cars currently being manufactured are roller bearing equipped as standard practice.

2. Calculations of social costs and benefits resulting from the accelerated conversion of the Canadian railway revenue car fleet from plain bearing to roller bearing equipment assume plain bearing car retirements continue at 4,000 to 5,000 annually and replacement cars are roller bearing equipped. It is also assumed that Canadian railway voluntary conversions continue at annual rates of 1,000 to 1,500 and that once the fleet is 75% roller bearing equipped, no further conversions take place. Roughly 25% of the existing Canadian-based railway fleet was manufactured prior to 1950. The age of this equipment dictates against its conversion for reasons of efficiency.

3. Car utilization: miles per plain bearing car per year and miles per roller bearing car per year are assumed to remain constant.

4. Forecasts of the international oil price indicate an escalation of 2% per annum in real terms for the period 1982 to 1985 and 1% per annum in real terms for the period 1986 to 1990. For the period

1991 to 2000, the assumption is that the international oil price will remain constant in real terms. The source of this forecast is the "NEB Reasons for Decision in the matter of an application under Part III of the National Energy Board Act of Trans-Quebec and Maritimes Pipeline Inc.", July, 1981, page 9-3.

5. Calculations of social costs resulting from the hot box and dragging equipment detector installation program have been based on data available for the two Class I railways, namely, Canadian Pacific and Canadian National Railways. This program has minimal impact upon the Class II railways due to limited track ownership in populated areas.

6. Calculations of social costs resulting from the hot box and dragging equipment detector installation program assume that gateway inspection points, as well as twenty-mile interval inspection points, will be protected through the use of hot box and dragging equipment detectors (HBD). Mechanical inspections will be performed at these inspection locations only until such time as HBDs can be installed and placed in operation.

7. A mechanical inspection is a physical inspection conducted by railway employees. Annual mechanical inspection costs for any single inspection point have been assumed to be the aggregate of estimated annual maintenance costs for an HBD and the capital charges for a single installation, excluding an allowance for income tax. The cost of capital rate used in the development of this estimate is based upon the 1980 R.T.C. approved cost of capital rates. The mechanical inspection cost

thus imputed will, in many cases, inadequately reflect costs to be incurred. This will be at least partially offset by cost inflation under the foregoing assumption. It is recognized that installation of HBDs, at some inspection points, will not be cost-warranted given the annual volume of special dangerous commodity traffic.

8. Calculations of social costs resulting from the HBD installation program assume a maximum annual installation capability of 60, for each Class I railway. It is further assumed that an HBD installed in 1982 becomes operational in 1983, i.e., a lag time of one year between HBD delivery and operation.

4.3 Proposed Regulation - Roller Bearings

"Canadian Railways are to convert to roller bearings sufficient cars to ensure that 75 percent of their owned and leased revenue car fleet are roller bearing equipped by December 31, 1987 (year-end progress reports are to be submitted by each railway to the R.T.C.). As well, all cars newly acquired or leased by Canadian railways shall be roller bearing equipped."

4.3.1 The Costs

Net plain to roller bearing car conversion costs amount to approximately \$4,000 per car. This estimate is based upon new material costs per car including labour for conversion less the aggregate of the value of reclaimed materials and the value of scrap recoveries. The conversion program involves costs of \$18,000,000 to \$24,000,000 (1981 \$)

per year for six years commencing in 1982, assuming 4,500 to 6,000 cars are converted annually and a Canadian 1981 revenue fleet of 160,000 cars of which 55,000 are roller bearing equipped.

The rate of regulation induced conversions is derived as follows:

$$\begin{aligned}\text{Number of cars to be converted/replaced} &= .75(160,000) - 55,000 \\ &= 65,000 \\ &\simeq 11,000/\text{year}\end{aligned}$$

Conversions and Replacements per year

	<u>Low</u>	<u>High</u>
Total	11,000	11,000
Replacements	-5,000	-4,000
Voluntary Conversions	<u>-1,500</u>	<u>-1,000</u>
Regulated Conversions	4,500	6,000

The present value of the cost of the conversion program, utilizing a 10% real social discount rate, is therefore in the order of \$78 to \$105 million (1981 \$).

4.3.2 The Benefits

The principal social benefits resulting from the accelerated conversion of the Canadian railway revenue car fleet from plain bearing to roller bearing equipment are:

- (a) reduced car maintenance costs;
- (b) reduced fuel costs;
- (c) reduced changeout costs; and
- (d) reduced incidence of over-heated journals (hot boxes)
resulting from bearing failure.

This latter benefit is of primary importance and reflects the degree to which the regulation achieves its objective, namely, the improved safety of rail operations in Canada.

Secondary benefits accrue from the reduced incidence of over-heated journals resulting from journal failure. These would include reduced costs incurred for repairs to or replacements of rolling stock, track and freight due to derailments, which were bearing-failure induced.

Reduced Car Maintenance Costs

The design characteristics of roller bearings render superfluous much of the on-going maintenance required by plain bearings (i.e. the necessity for frequent servicing of plain bearings and their associated journal box components).

Maintenance savings amount to approximately \$216 per car converted per year. Reference is made to CP Exhibit 6, entitled "Economics Associated with CP Rail's Wheel Conversion Program" submitted to the C.T.C. "Show Cause" Hearing on Railway Safety. (See Appendix 2.)

Using a real social discount rate of 10%, and car conversion rates of from 4,500 to 6,000 per year, the present values of maintenance savings range from \$30,000,000 to \$45,000,000 (1981 \$).

Reduced Fuel Costs

Fuel savings are approximately 160 gallons per car converted per year. Reference is made to CP Exhibit 6, entitled "Economics Associated with CP Rail's Wheel Conversion Program", submitted to the C.T.C. "Show Cause" Hearing on Railway Safety.

Benefits to society arising from reduced fuel consumption have been calculated using \$38 per barrel as the landed price for offshore crude and assuming the diesel price to be 125% of the crude feedstock price.

With a real social discount rate of 10%, and car conversion rates of from 4,500 to 6,000 per year, the present values of fuel savings range from \$33,000,000 to \$50,000,000 (1981 \$).

Reduced Changeout Costs

Changeout savings have been calculated based upon the following assumptions:

(a) Plain bearing cars require complete (8 bearings) changeout every 7 years;

(b) Roller bearing cars require complete (8 bearings) changeout every 10 years.

Plain bearing car changeout costs amount to approximately \$2,180 per car every 7 years whereas roller bearing car changeout costs are approximately \$3,988 per car every 10 years. Reference is made to CP Exhibit 6, entitled "Economics Associated with CP Rail's Wheel Conversion Program" submitted to the C.T.C. "Show Cause" Hearing on Railway Safety.

Using a real social discount rate of 10%, and car conversion rates of from 4,500 to 6,000 per year, the present value of changeout savings are in the order of \$3,000,000 to \$4,000,000 (1981 \$).

Net Social Cost of the Conversion Program

The resulting net social cost of the conversion program when utilizing a 10% real social discount rate is from \$6,000,000 to \$12,000,000 in 1981 dollars. No dollar value benefits have been factored

into the above net cost to account for the reduced derailments associated with the implementation of the conversion program.

Reduced Incidence of Over-Heated Journals

Undetected over-heated journals (hot boxes) result in burnt-off journals and can lead to derailments.

In April of 1980, a study was undertaken by the Research Branch of the C.T.C. to assess the relative reliabilities of roller bearings and friction/plain bearings on railway freight cars. The reliability model chosen for the analysis is characterized by a lack-of-memory property, which implies that previous use does not affect future life. The limited operational performance data available and the absence of life test data from laboratory or controlled field experiments precluded the use of a more sophisticated model capable of considering age.

The study concluded that in 1978 the survival probability past 25,000 miles for a freight car equipped with roller bearings was 0.998 and for a freight car equipped with friction bearings was 0.970. Therefore, based upon these findings and limited by the assumptions incorporated in the analysis, the estimated number of overheated journals averted resultant from the accelerated conversion program ranges from 8,000 to 14,000 over a twenty-year time horizon. The incremental cost of this reduction is \$430 - \$1,500/over-heated journal averted (hot box averted).

Reference is made to Appendix 3, "Preliminary Assessment of the Relative Reliabilities of Roller Bearings and Friction Bearings on Railway Freight Cars".*

Secondary Benefits

The expected reduction in the incidence of over-heated journals and, by inference, derailments induced by bearing failures will generate a number of societal savings.

Among these secondary benefits is a decline in the damage to property and lading caused by derailments. Monetary estimates of the future savings arising from reduced damage are not available. For the years 1976 to 1980 inclusive, however, CN and CP derailments due to bearing failures have caused damages estimated at \$18,000,000. The order of magnitude of potential savings is, therefore, significant.

4.4 Proposed Regulation - Gateway and Interval Inspections

"Trains carrying any special dangerous commodity shall undergo a "gateway" inspection, at minimum consisting of a hot box and dragging equipment detector or a mechanical inspection by railway employees before entering a populated area. A similar further inspection at no more than 20 mile intervals relative to the location of the gateway inspection points, within the populated area will be required unless the special dangerous commodity train operates below 15 m.p.h.

* Quantalytics Inc. presented a study entitled "A Risk Analysis Of Options For Transporting Dangerous Commodities By Rail in Canada" to the Show Cause Hearing. This study was considered by staff as related material but the conclusions were not directly applicable to the proposed regulation under study.

The gateway inspection is to take place no closer than 3 miles and no more than 20 miles from the boundary of a populated area.

For the purposes of this requirement a populated area is defined as a densely populated area and priority is granted those areas in which evacuation in the event of an emergency would be very difficult.

Due to practical difficulties in implementing the requirement it will be phased in starting with the largest cities. It will be effective:

- (a) immediately upon RTC approval of plans to be submitted by each railway within sixty (60) days hereof in census metropolitan areas with a population of over 100,000,
- (b) October 1, 1984 for populated areas with a population of 50,000 to 100,000 but not with a census metropolitan area and
- (c) October 1, 1987 for populated areas with a population of 10,000 to 50,000 but not within a census metropolitan area."

4.4.1 The Costs

The capital cost of a hot box and dragging equipment detector (HBD) is approximately \$95,640. This figure is net of federal sales tax, includes estimated unit installation costs of \$25,000 and provides an allowance for basic power service. HBD operation and maintenance is roughly \$8,000 per unit-year.

The imputed annual mechanical inspection cost for a single inspection point is \$20,000. Reference is made to Section 4.2, Assumption 7.

Cost calculations for the HBD installation program assume a total of 379 inspection locations, disaggregated as follows:

- 120 gateway and interval inspection points for census metropolitan areas (CMA);
- 41 gateway inspection points for cities of 50,000 to 100,000, not within a CMA; and
- 218 gateway inspection points for cities of 10,000 to 50,000, not within a CMA.

The present value of the cost of the HBD installation program, utilizing a 10% real social discount rate is in the order of \$48,000,000 (1981 \$).

4.4.2 The Benefits

Hot box detectors are trackside monitoring devices which measure the heat radiated by wheels or wheel journals of passing trains.

A train approaching the detector site passes over circuits which activate the detector. The infrared detectors measure the difference between the ambient air temperature and the temperature of the outside surface of the wheel or journal box. The temperature difference is then processed by the electronics. There are two methods employed to analyze the heat information: a central readout recorder system, and an automatic

display board system. Both systems are in use on Canadian railway lines. When unsafe conditions are detected, the train is stopped and inspected.

It is difficult to give a precise picture of the effectiveness of HBD's and of the program to date. The reasons include changing traffic levels and types of traffic, and most importantly the increasing number of roller bearings. Further, past statistics are obscured by the increasing number of detector locations. CP Rail's program, however, has been shown to have reduced the incidence of burn-offs by as much as 95% of previous rates.*² This appears to be in line with the American experience. In a Special Investigation Report entitled "Recent Accident History of Hot Box Detector Data Management", dated August 11, 1981, it was concluded that:

"The hot box detector has played a major role in reducing accidents that result from overheated railroad journal bearings."**

The spacing criteria incorporated in the proposed HBD installation program and regulations provide for the protection of population density centres, in accordance with the attendant risks to life and property.

* An excerpt from "Public hearing pursuant to Show Cause Orders Issued by the Railway Transport Committee. Written direct evidence of Canadian Pacific Limited - The Transportation of Dangerous Commodities by Rail", April 15, 1981. As CP Rail's program is relatively new, with placement and spacing criteria based upon historical data of the incidence of burned-off journals, these results must be qualified.

** NTSB Special Investigation Report "Recent Accident History of Hot Box Detector Data Management", August 11, 1981, NTSB-SIR-81-1.

The HBD installation program will reduce the risk of derailments to trains carrying dangerous goods. Potential societal savings arising from this reduction in risk are substantial. A current estimate of the total loss attributed to the Mississauga accident of November 10, 1979 is \$26.5 million. The HBD program will also reduce the risk of derailments to other trains which do not carry dangerous goods. While the potential for loss of life and property outside the railway right of way is minimal in the case of derailments not involving dangerous goods, damages to property and lading can be appreciable.

4.5 Proposed Regulation - Speed Restrictions

"In census metropolitan areas with a population of 100,000 or more ... trains carrying special dangerous commodities shall travel at no more than 35 mph and in areas of population from 50,000 to 100,000 where provisions for protection as defined in ... (item 4.4) have not been implemented, trains carrying special dangerous commodities shall travel at no more than 35 mph. In areas of population from 10,000 to 50,000 not protected as defined in ... (item 4.4) trains carrying special dangerous commodities shall travel at no more than 35 mph after October 1, 1987."

4.5.1 The Costs

Freight trains generally do not enter CMA's at speeds greater than 50 m.p.h. and, with few exceptions, these trains terminate there. The reduction in speed from 50 m.p.h. to 35 m.p.h. would, in the majority of cases, occur only a few miles prior to where it presently takes place and, in most instances, the train would have reduced speed to 15 m.p.h. at the twenty mile interval point.

With regard to cities with a population of between 10,000 and 100,000, trains frequently stop at such locations either to pick up or deliver goods and the 35 m.p.h. speed restriction would thus not affect their operation. Where trains do not stop, the distance over which the speed restriction would apply would be short and the additional time negligible.

It is considered that the additional time taken to travel through CMA's and cities due to the proposed speed restrictions would be minimal and that no significant cost would be incurred by the railway companies.

4.5.2 The Benefits

With regard to train speed restrictions, Mr. Justice Samuel G.M. Grange stated that "whatever may be the relationship between speed and derailment, the damage suffered upon a derailment must increase with the speed." Indeed, there is evidence indicating a direct relationship between post accident damage and train speed. In addition, at lower train speeds, a hot box is likely to take more time to go to failure.

The proposed speed restriction may reduce the likelihood of bearing failure related derailments in high population density areas and, in the event of a mishap, reduce the post accident damage.

4.6 Proposed Regulation - Tank Car Modifications

"Double Shelf Couplers

No specification 105 tank cars carrying any regulated commodity will be accepted for transport after June 30, 1982, unless equipped with double shelf couplers.

No specification 103, 111 or other CTC specification tank cars carrying any regulated commodity will be accepted for transport after February 28, 1985 unless equipped with double shelf couplers.

No tank car built after the date of issuance of this decision (September 30, 1981) will be accepted for transport unless equipped with double shelf couplers.

Head Shields

Only full headshields are to be used henceforth on new cars and for future retrofitting.

All new 105 tank cars constructed after December 31, 1981, with the exception of those constructed to a service pressure of 500 or more psi, shall be equipped with a tank head puncture resistance system equivalent to that now required for specification 112 and 114 tank cars or they will not be accepted for transport.

Thermal Protection

No specification 112 and 114 tank cars carrying any dangerous commodity will be accepted for transport after December 31, 1982 unless equipped with thermal protection.

All new 105 cars constructed after December 31, 1981 shall be equipped with thermal protection or insulation equivalent to the present requirements for 112 and 114 tank cars or they will not be accepted for transport.

Bottom Fitting Protection

All new cars equipped with bottom outlets or other bottom discontinuities built after December 31, 1981 shall have such outlets protected as set out in the AAR Specifications for Tank Cars or recessed below the surface of the tank shell or they will not be accepted for transport."

4.6.1 The Costs

Double Shelf Couplers

Under DOT (U.S.) regulations, it is mandatory for 105 tank cars to be equipped with double shelf couplers effective February 28, 1982. Other DOT specification tank cars, including 103 and 111 cars, must be so equipped effective February 28, 1985. Further, American regulations require all tank cars built after February 28, 1981 to be equipped with double shelf couplers.

Canadian tank cars, which are used in international service, must be equipped in compliance with U.S. regulations. In recognition of this requirement, the retrofitting of Canadian tank cars with double shelf couplers was in progress prior to the issue of the "Show Cause" Hearing Decision on Railway Safety.

Canadian tank car companies manufacture cars in accordance with the most recent and stringent North American requirements. The diseconomies attendant with captive fleet conditions established an environment conducive to double shelf couplers becoming standard equipment for all new tank cars manufactured in Canada. It is therefore concluded that this regulation will not impose significant additional costs.

Head Shields

Under U.S. regulations, half-head shields are acceptable. Under the proposed regulation, half-head shields will continue to be acceptable for existing Canadian tank cars. However, the regulation will require all new cars to be built with full head shields and all existing cars to be so equipped whenever they undergo a major retrofit.

The full head shield requires end sections made of 1/2 inch steel plate while the half-head shield requires the lower portion to be of 1/2 inch steel plate and the upper section of 1/8 inch steel plate. Whereas the half-head shield requires less material, there is more labour required to join the 1/2 inch material to the 1/8 inch material. Therefore, no significant costs will be imposed by the proposed regulation.

Thermal Protection

U.S. regulations required thermal protection on all cars carrying flammable compressed gases, effective December 31, 1980. C.T.C. General Order 1979-1, dated January 22, 1979, required that all 112 and 114 tank cars carrying flammable compressed gases be equipped with a thermal protection system.

As approximately 90% of Specification 112 and 114 tank cars are engaged in the transportation of flammable compressed gases, Canadian tank car companies completed the retrofit of that portion of the fleet by June 30, 1981.

The proposed regulation requires retrofit of the remainder of the 112 and 114 fleet. Approximately 300 cars are affected. The present value of the additional cost imposed upon tank car companies is in the order of \$4,091,000 (1981 \$), utilizing a 10% real social discount rate. Savings due to the increased operational flexibility of the fleet will have a tendency to offset a portion of this cost. Shippers will realize costs associated with the reduced payload per car and with the increased tare weight of retrofitted cars.

The proposed regulation does not involve a retrofit program for C.T.C. Specification 105 tank cars. The requirement for thermal protection on new 105 tank cars involves an increase of approximately 3% in the manufacturing cost of each car.

Bottom Fitting Protection

Under A.A.R. regulations, it is mandatory that all new cars equipped with bottom outlets or bottom discontinuities have such outlets protected or recessed below the surface of the tank shell. Conformance with A.A.R. regulations is compulsory for all railways engaged in interchange traffic, both in the U.S. and Canada.

In order to maintain flexibility in fleet assignment, Canadian tank car companies equip all newly constructed cars with bottom fitting protection, as standard practice. Therefore, it is expected that the proposed regulation will not impose additional costs upon Canadian tank car companies.

4.6.2 The Benefits

Under a cooperative program of the Railway Progress Institute and the Association of American Railroads, the Railroad Tank Car Safety Research and Test Project tabled a report on May 15, 1981, entitled "Phase 02 Report on Effectiveness of Shelf Couplers, Head Shields and Thermal Shields". The report presented study findings vis-à-vis the safety improvement realized by the incorporation of shelf couplers, head shields and thermal shields on 112 (114) tank cars required under U.S. regulation HM-144. Accident data on punctures and fire-induced ruptures prior to, during, and subsequent to the HM-144 retrofit period was assembled and analyzed. Study results were updated in a supplement to the aforementioned report on August 20, 1981. The American experience indicates that the frequency of head punctures, subsequent to the retrofit period, is about 1/20th the previous rate. The average rate of fire-induced ruptures has dropped to about 1/16th the previous rate.

The report cautioned against full confidence in the accuracy of the performance comparisons, due to the limited service experience of retrofitted cars (2 1/4 years). It was concluded, however, that the retrofit program had caused a significant reduction in the incidence of tank car punctures and fire-induced ruptures.

In the light of the American experience, it is expected that the proposed regulations pertaining to tank cars will effect substantial returns in terms of increased safety, and decreased damage to property and lading.

Bottom outlets or bottom discontinuities will be protected under the proposed regulation. This will minimize the likelihood of spillage due to shearing off of the bottom outlet or discontinuity during derailments.

4.7 Sensitivity Analysis

The present value of the cost of the roller bearing conversion program (net of fuel, maintenance and changeout savings), the HBD installation program and the thermal protection retrofit program, utilizing a 10% real social discount rate, is from \$58,300,000 to \$64,900,000 (1981 \$).

A sensitivity analysis was performed to determine the extent to which these results are dependent upon the choice of discount rate.

At a 5% discount rate, the present value of the cost of the proposed regulations having significant cost implications, identified above, ranges from \$40,500,000 to \$64,200,000 (1981 \$).

The cost range narrows to \$62,700,000 to \$63,900,000 (1981 \$) when a 15% real social discount rate is applied.

As reflected in the following table, the cost of the roller bearing conversion program, the thermal protection retrofit program and the HBD installation program is front-ended, i.e. incurred early in the study horizon. The stream of cost savings resulting from the roller bearing conversion program, however, extends over the 20 year horizon.

TABLE OF RESULTS

	<u>5% Discount Rate</u> (\$000)	<u>10% Discount Rate</u> (\$000)	<u>15% Discount Rate</u> (\$000)
<u>HBD INSTALLATION PROGRAM</u>			
Costs:	\$63,379	\$47,998	\$38,475
<u>TANK CAR MODIFICATIONS - THERMAL PROTECTION</u>			
Costs:	\$ 4,286	\$ 4,091	\$ 3,913
<u>ROLLER BEARING CONVERSION PROGRAM</u>			
Conversion Rate = 4500 cars/yr.			
Costs:	\$91,362	\$78,395	\$68,120
Maintenance	(42,692)	(29,647)	(21,561)
Fuel	(47,506)	(32,837)	(23,772)
Changeout	(4,615)	(3,042)	(2,416)
Net subtotal 1	(\$3,451)	\$12,869	\$20,371
Conversion Rate = 6000 cars/yr.			
Costs:	\$121,817	\$104,526	\$90,827
Maintenance	(67,464)	(44,633)	(31,370)
Fuel	(75,339)	(49,589)	(34,678)
Changeout	(6,153)	(4,056)	(3,221)
Net subtotal 2	(\$27,139)	\$6,248	\$21,558
TOTAL 1	\$64,214	\$64,958	\$62,759
TOTAL 2	\$40,526	\$58,337	\$63,946

5.0 ANALYSIS OF THE NON-ALLOCATIVE EFFECTS

5.1 International Trade Implications

While the material required for the roller bearing retrofit program and the hot box detector installation program resulting from these new regulations must be imported, the direct effects upon the Merchandise Trade Balance would be small. The regulation induced increase in roller bearing and HBD imports amounts to an average of approximately \$27.5 million to \$35.5 million annually for the six-year period commencing in 1982. In the case of all years, this is less than 0.05% of the forecasted level of total Canadian imports.

5.2 Distribution of Income

The maximum present value of the net cost of the roller bearing conversion program, when added to the present value cost of the HBD installation program, amounts to approximately \$60,000,000 (1981 \$). This total is less than 1.5% of 1980's aggregate operating expenses in the railway industry.

Rate implications are not easily identifiable given that transport market conditions dictate the extent to which cost increases can be passed on to shippers through higher rates.

5.3 Market Structure and Competition

The rail transport industrial sector is a regulated market dominated by two very large firms. It is estimated that Canadian National Railways and Canadian Pacific Railway account for over 90% of all rail business in Canada. It is not expected that this new regulation will have a significant impact on market structure and competition amongst the railways. Existing barriers to entry are already high due to the capital intensive nature of the industry.

It should be noted that the smaller Class II railways do not, as a rule, compete with the Class I railways. Therefore, there is no survival risk incurred by the Class II companies due to divergent inter-class capability to handle increased costs resulting from the proposed regulations. Furthermore, many Class II railways have access to financing equal to that of the Class I railways. This is due to the fact that many Class II's are part of larger corporate entities with good access to the capital markets.

6.0 CONCLUSION

The increased use of roller bearing equipped railway cars will result in a reduced incidence of over-heated journals. Undetected over-heated journals result in burnt-off journals and can lead to derailments. The incremental cost of this reduction is \$430 - \$1,500/over-heated journal averted (hot box averted).

The hot box detector installation program will reduce the risk of derailments through early identification of unsafe conditions.

Train speed restrictions may reduce the likelihood of bearing failure related derailments in high population density areas and, in the event of a mishap, reduce the post accident damage.

The proposed regulation pertaining to railway tank car modifications will reduce the frequency of tank car punctures and fire-induced ruptures. The regulation will also minimize the likelihood of spillage due to shearing off of bottom outlets or discontinuities on tank cars during derailments.

APPENDICES

Appendix 1



RAILWAY TRANSPORT COMMITTEE

ORDER NO. R-32792

October 15, 1981

IN THE MATTER OF the transportation of
dangerous commodities by rail;

IN THE MATTER OF the Show Cause hearing
of the Railway Transport Committee and
the decision on railway safety dated
September 30, 1981, resulting therefrom
(hereinafter referred to as "the Show
Cause Decision");

WHEREAS in the Show Cause Decision it
was found that changes were required in
the operation and speed of trains
carrying certain dangerous commodities
through certain densely populated areas
in order to provide for the protection
and safety of the public; and

WHEREAS it was determined in the Show
Cause Decision that inspection of
trains carrying certain dangerous
commodities prior to entering certain
densely populated areas and at 20 mile
intervals within census metropolitan
areas was necessary in the interest of
public safety.

File No. 50076.1

IT IS ORDERED THAT:

Canadian Pacific Limited shall

1. file with the Secretary of the
Railway Transport Committee on or
before November 30, 1981 plans for
the immediate implementation of

COMITE DES TRANSPORTS PAR CHEMIN DE FER

ORDONNANCE N° R-32792

Le 15 octobre 1981

RELATIVE au transport de marchandises
dangereuses par chemin de fer;

RELATIVE à l'audience de sommation du
Comité des transports par chemin de fer
et à la décision subséquente (ci-après
appelée la décision de sommation), du
30 septembre 1981, sur la sécurité des
chemins de fer;

ATTENDU que conformément à la décision de
sommation, il appert qu'il est nécessaire
de modifier l'exploitation et la vitesse
des trains transportant certaines marchandises
dangereuses lorsqu'ils entrent dans des
zones densément peuplées afin de garantir
la protection et la sécurité du public; et

ATTENDU que la décision de sommation a
déterminé qu'il était nécessaire, dans
l'intérêt de la sécurité du public,
d'inspecter les trains qui transportent
certaines marchandises dangereuses avant
qu'ils ne passent dans certaines zones
densément peuplées et à tous les 20 milles
dans les régions métropolitaines de
recensement.

Dossier n° 50076.1

IL EST ORDONNE CE QUI SUIT:

Canadien Pacifique Limitée devra

1. déposer, en vue de leur mise en oeuvre
immédiate, auprès du Secrétaire du Comité
des transports par chemin de fer et au
plus tard le 30 novembre 1981, des plans

SEE ORDER
3272
No.

ORDER No. R-32792

ORDONNANCE N^O R-32792

gateway and 20 mile interval inspections (as prescribed in the Show Cause Decision) within the census metropolitan areas listed in Schedule A to this Order, of trains carrying one or more full carloads of any of the commodities listed in Schedule B to this Order,

2. effective immediately, ensure that all trains carrying one or more full carloads of any of the commodities listed in Schedule B to this Order do not travel at any speed greater than 35 m.p.h. while within any of the census metropolitan areas listed in Schedule A to this Order,

3. upon Railway Transport Committee approval of the plan submitted pursuant to clause 1, ensure that trains carrying one or more full carloads of the commodities listed in Schedule B to this Order do not travel at any speed greater than 35 m.p.h. while within any city, town or place with a population of between 50,000 and 100,000 (as identified in the decennial census of population conducted by Statistics Canada) unless gateway inspections (as prescribed in the Show Cause Decision) are performed on such trains prior to entering such cities, towns or places, (any city, town or place within a census metropolitan area listed in Schedule A to this Order is excluded from this Clause),

prévoyant des inspections aux points d'échange et à tous les 20 milles (tel que prescrit dans la décision de sommation) dans les régions métropolitaines de recensement énumérées à l'annexe A de cette ordonnance et ce, à l'égard des trains transportant un ou plusieurs chargements complets de l'une quelconque des marchandises énumérées dans l'annexe B de cette ordonnance,

2. s'assurer dorénavant que tous les trains transportant un ou plusieurs chargements complets de l'une quelconque des marchandises énumérées dans l'annexe B de cette ordonnance, ne dépassent pas 35 milles à l'heure lorsqu'ils se trouvent dans l'une quelconque des régions métropolitaines de recensement énumérées dans l'annexe A de cette ordonnance,

3. s'assurer, après approbation par le Comité des transports par chemin de fer du plan présenté conformément à la clause 1, que les trains qui transportent un ou plusieurs chargements complets de marchandises dangereuses énumérées dans l'annexe B de cette ordonnance, ne dépassent pas 35 milles à l'heure lorsqu'ils se trouvent dans toute cité, ville ou agglomération dont la population varie entre 50 000 et 100 000 habitants (selon le recensement décennal établi par Statistique Canada) à moins que des inspections au point d'échange, (tel que décrit dans la décision de sommation) soient effectuées sur ces trains avant qu'ils n'entrent dans ces cités, villes ou agglomérations (toute cité, ville ou agglomération située dans une région métropolitaine de recensement énumérée dans l'annexe A de cette ordonnance n'est pas assujettie à cette clause),

ORDER No. R-32792

ORDONNANCE N^O R-32792

4. effective October 1, 1984, perform gateway inspections (as prescribed in the Show Cause Decision) on trains carrying one or more full carloads of any of the commodities listed in Schedule B to this Order prior to entering any city, town or place with a population of between 50,000 and 100,000, (any city, town or place within a census metropolitan area listed in Schedule A to this Order is excluded from this Clause), and

5. effective October 1, 1987, perform gateway inspections (as prescribed in the Show Cause Decision) on trains carrying one or more full carloads of any of the commodities listed in Schedule B to this Order prior to such a train entering any city, town, village or place with a population of between 10,000 and 50,000 (as identified by the decennial census of population conducted by Statistics Canada) (any city, town, village or place within a census metropolitan area listed in Schedule A to this Order is excluded from this Clause).

4. effectuer, à partir du 1^{er} octobre 1984, des inspections au point d'échange (tel que prescrit dans la décision de sommation) des trains qui transportent un ou plusieurs chargements complets de l'une quelconque des marchandises énumérées dans l'annexe B de cette ordonnance, avant que ces trains n'entrent dans toute cité, ville ou agglomération dont la population varie entre 50 000 et 100 000 habitants (toute cité, ville ou agglomération située dans une région métropolitaine de recensement énumérée dans l'annexe A de cette ordonnance n'est pas assujettie à cette clause), et

5. effectuer, à compter du 1^{er} octobre 1987, des inspections au point d'échange (tel que prescrit dans la décision de sommation) de tous les trains qui transportent un ou plusieurs chargements complets de l'une quelconque des marchandises énumérées dans l'annexe B de cette ordonnance avant que ces trains n'entrent dans toute cité, ville, village ou agglomération dont la population varie entre 10 000 et 50 000 habitants (d'après le recensement décennal effectué par Statistique Canada)(toute cité, ville, village ou agglomération situé dans une région métropolitaine de recensement énumérée dans l'annexe A de cette ordonnance n'est pas assujetti à cette clause).

(signed) (signature)

J. O'Hara

Secretary

Secrétaire

Railway Transport Committee

Comité des transports par chemin de fer

SCHEDULE A

CENSUS METROPOLITAN AREAS*

St. John's, Newfoundland
Halifax, Nova Scotia
Saint John, New Brunswick
Chicoutimi, Quebec
Quebec, Quebec
Trois Rivières, Quebec
Montreal, Quebec
Ottawa/Hull, Ontario/Quebec
Oshawa, Ontario
Toronto, Ontario
Hamilton, Ontario
St. Catharines, Ontario
Kitchener, Ontario
London, Ontario
Windsor, Ontario
Sudbury, Ontario
Thunder Bay, Ontario
Winnipeg, Manitoba
Regina, Saskatchewan
Saskatoon, Saskatchewan
Calgary, Alberta
Edmonton, Alberta
Vancouver, British Columbia
Victoria, British Columbia

* CMA Refers to the main labour market area of an urbanized core (or continuously built-up area) having 100,000 or more population. CMAs are created by Statistics Canada and are usually known by the name of the urban area forming their urbanized core. They contain whole municipalities (or census subdivisions). CMAs are comprised of (1) municipalities completely or partly inside the urbanized core, and (2) other municipalities, if (a) at least 40% of the employed labour force living in the municipality works in the urbanized core, or (b) at least 25% of the employed labour force working in the municipality lives in the urbanized core.

Since a CMA must contain whole census subdivisions, its limits may fall within, or extend beyond, the actual labour market area. The differences may be significant in those parts of Canada where census subdivisions cover particularly large areas of land. Census metropolitan areas may also differ from Metropolitan Areas designated by local authorities for planning or other purposes.

ANNEXE A

RÉGIONS MÉTROPOLITAINES DE RECENSEMENT (R.M.R.)

St. John's (Terre-Neuve)
Halifax (Nouvelle-Ecosse)
St. John (Nouveau-Brunswick)
Chicoutimi (Québec)
Québec (Québec)
Trois Rivières (Québec)
Montréal (Québec)
Ottawa/Hull (Ontario/Québec)
Oshawa (Ontario)
Toronto (Ontario)
Hamilton (Ontario)
St. Catharines (Ontario)
Kitchener (Ontario)
London (Ontario)
Windsor (Ontario)
Sudbury (Ontario)
Thunder Bay (Ontario)
Winnipeg (Manitoba)
Regina (Saskatchewan)
Saskatoon (Saskatchewan)
Calgary (Alberta)
Edmonton (Alberta)
Vancouver (Colombie-Britannique)
Victoria (Colombie-Britannique)

*R.M.R. désigne le principal bassin de recrutement de la main-d'oeuvre d'un noyau urbanisé (ou zone bâtie en continu) ayant une population de 100 000 habitants ou plus. Créées par Statistique Canada, les R.M.R. portent le nom, en général, de la région urbaine constituant leur noyau urbanisé et regroupent des municipalités entières (ou subdivisions de recensement). Les R.M.R. comprennent (1) des municipalités situées totalement ou en partie dans le noyau urbanisé et (2) d'autres municipalités, à condition (a) qu'au moins 40% de la population active occupée qui réside dans la municipalité travaille dans le noyau urbanisé, ou (b) qu'au moins 25% de la population active occupée qui travaille dans la municipalité réside dans le noyau urbanisé.

Comme une R.M.R. se compose de subdivisions de recensement entières, ses limites peuvent correspondre à celles du bassin de recrutement de la main-d'oeuvre comme tel ou même s'étendre au-delà. Les différences à cet égard peuvent être notables, particulièrement dans les régions du Canada où les subdivisions de recensement occupent une grande superficie. Une région métropolitaine de recensement peut également différer d'une région métropolitaine, ainsi désignée par les autorités locales à des fins de planification ou autres.

SCHEDULE B

LIST NO.1

Commodity Name

Amatol (high explosives)
Anhydrous Ammonia
Anhydrous Hydrofluoric Acid
Chlorine
Isobutane or Liquified Petroleum Gas
Liquified Petroleum Gas
Motor Fuel Antiknock Compound
Propane or Liquified Petroleum Gas
Sulphur Dioxide
Vinyl Chloride
Acrylonitrile
Ammunition for cannon with explosive projectiles
Butadiene, Inhibited
Ethylene Oxide
High Explosives
High Explosives Liquid
Hydrochloric Acid Anhydrous, Hydrogen Chloride
Phosphorus White or Yellow in water
Ammunition for cannon illuminating projectiles
Ammunition for cannon with smoke projectiles
Ammunition for small arms with explosive projectiles
Aqua Ammonia Solution
Blasting caps-more than 1000
Calcium Phosphide
Calcium Cyanide
Carbon Monoxide
Crude Nitrogen Fertilizer Solution
Compressed Gases n.o.s.
Cyanide of Potassium, Liquid
Cyanide of Sodium, Liquid (Sodium Cyanide)
Cyanide of Sodium, Solid (Sodium Cyanide)
Detonating Fuses Class A
Detonating Primers
Detonating Fuses Class A explosives, radioactive
Dimethylamine Anhydrous
Diphenylamine chlorarsine, Gas Liquid or solid
Electric Blasting Caps more than 1000
Ethane
Ethylene
Explosive Bomb
Explosive Mine
Explosive Projectile
Explosive Torpedo
Fertilizer Ammoniating Solution containing free ammonia

LIST 1 (cont'd)

Commodity Name

Fuses Detonating Containing Class A explosives
Hand Grenades
Hydrocarbon Gas, Liquified
Hydrocyanic Acid, Liquified
Hydrocyanic Acid (Prussic), Liquid
Hydrogen Sulphide
Isobutylene or Liquified Petroleum Gas
Jet Thrust Unit (JATO), Class A Explosives
Low Explosives
Methane
Methylamine Anhydrous
Nonliquified Hydrocarbon Gas
Oleum
Oxygen Pressurized Liquid
Propellant Explosives Class A
Pyroforic Liquids, n.o.s.
Radioactive material low specific activity
Rocket Ammunition with explosive projectiles
Silver Cyanide
Sodium Metallic

LIST 2

Commodity Name

Acetone Cyanhydrin
Acid Picric
Ammonium Picrate
Ammunition Chemical
Ammunition for Cannon with Gas Projectiles
Ammunition for Cannon with Incendiary Projectiles
Ammunition for Small Arms with Incendiary Projectiles
Barium Cyanide, Solid
Black Blasting Powder
Black Pellet Powder
Black Powder
Blasting Caps with metal clad mild detonating fuse-more than 1000
Blasting Caps with safety fuse-more than 1000
Boosters, explosive
Bromacetone, Liquid
Brombenzyl Cyanide, Liquid
Bromine
Bromine Pentafluoride
Bromine Trifluoride
Bursters, explosives
Calcium Phosphide
Choracetophenone Gas, liquid or solid
Chlorpicrin and Non-flammable nonliquified compressed gas mixtures
Chlorpicrin and methyl chloride mixtures
Compressed Gases, n.o.s.
Copper Cyanide
Crotonaldehyde
Cyanides of Cyanide mixtures, dry
Cyanide of Potassium, Solid
Cyanogen Bromide
Cyanogen Chloride containing less than .9% water
Cyanogen Gas
Cyclopropane
Explosives radioactive
Dimethyl Ether
Dephenyl chlorarsine Solid
Diphosgene
Ethylchloroarsine
Fluorine
Hexaethyl Tetraphosphate and compressed gas mixture
Hydrobromic Acid
Hydrobromic acid, anhydrous
Hydrocyanic acid, solutions
Hydrogen hydrofluoric and sulphuric acids, mixtures
Hydrogen Bromide
Hydrogen gas, nonliquified
Hydrogen, Liquified
Ignitors Jet Thrust (JATO)

LIST 2 (cont'd)

Commodity Name

Class A explosives
Ignitors Rocket Motor
Class A Explosives
Igniting Explosives
Irritating Agents n.o.s.
Lead Cyanide
Lewisite
Liquified Hydrocarbon gas
Liquified Non flammable gases charged with nitrogen, carbon dioxide or air
Low blasting explosives
Mercuric Chloride
Mercuric Cyanide Solid
Methyldichlorasine
Methyl Mercaptan
Monochloracetone Stabilized
Mustard Gas
Nitrating (mixed) Acid
Nitric Oxide
Nitrogen fertilizer, solution
Nitrogen Tetroxide, Liquid
Nitrogen Tetroxide - Nitric Acid mixtures containing up to 33.2% weight
Nitric Oxide
Nitroglycerin, Spirits of
Nitrosyl Chloride
Nitrous Oxide
Organic Phosphates n.o.s. mixed with compressed gas
Pentaborane
Perchlorates n.o.s.
Perchloric acid, not in excess of 72%
Phenylcarbylamine Chloride
Phenyldichlorarsine, Liquid
Phosgene (disphosgene)
Phosphorus, white or yellow, dry
Poisonous Liquid or Gas n.o.s.
Police Grenades Poison Gas Class A
Pyro Sulphuryl Chloride
Radioactive Material, exempt Articles, exempt quantity, fissile,
normal form
Radioactive Material Special Form
Rifle Grenades
Rocket Ammunition with illuminating projectiles
Rocket Ammunition with gas projectiles
Rocket Ammunition with incendiary projectiles
Rocket Ammunition with smoke projectiles
Rocket Motors Class A Explosives
Silicon Tetrafluoride
Sulphur Hexafluoride
Sulphur Trioxide Stabilized
Sulphuryl Chloride
Sulphuryl Fluoride

LIST 2 (cont'd)

Commodity Name

Supplementary Charges (explosive)
Tear Gas Candles
Tear Gas Grenades
Tear Gas Material Liquid, or Solid n.o.s.
Tetraethyl Dithio Pyrophosphate and compressed gas mixture
Tetraethyl Pyrophosphate and compressed gas mixture
Tetrafluoroethylene, Inhibited
Tetranitromethane
Trimethylamine Anhydrous
Trinitrobenzene, wet (not to exceed 16 ounces)
Vinyl Fluoride, Inhibited
Vinyl Methyl Ether, Inhibited
Xylol Bromide
Zinc Cyanide

ANNEXE B

LISTE n° 1

Nom des produits

Amatol (Explosif puissant)
Ammoniac anhydre
Acide fluorhydrique anhydre
Chlore
Isobutane ou Gaz de pétrole liquéfié
Gaz de pétrole liquéfié
Mélanges antidétonants pour carburants
Propane ou Gaz de pétrole liquéfié
Anhydride sulfureux
Chlorure de vinyle
Nitrile acrylique
Munitions pour canon à projectile explosif
Butadiène stabilisé
Oxyde d'éthylène
Explosifs puissants
Explosifs puissants sous forme liquide
Acide chlorhydrique anhydre, Chlorure d'hydrogène
Phosphore blanc ou jaune dans l'eau
Munitions pour canon avec projectile éclairant
Munitions pour canon avec projectile fumigène
Munitions pour armes de petits calibres avec projectiles explosifs
Ammoniac en solution aqueuse
Amorces détonantes (plus de 1 000)
Phosphure de calcium
Cyanure de calcium
Monoxide de carbone
Engrais azotés en solutions sous forme brute
Gaz comprimés
Cyanure de potassium, liquide
Cyanure de sodium, liquide
Cyanure de sodium, solide
Cordeau détonant classe A
Amorce détonante
Cordeau détonant, explosif classe A, radioactif
Diméthylamine anhydre
Diphénylamine - chlorarsine, solide, liquide ou gazeux
Amorces détonantes électriques (plus de 1 000)
Ethane
Éthylène
Bombe avec charge d'éclatement
Mine avec charge d'éclatement
Projectile avec charge d'éclatement
Torpilles avec charge d'éclatement
Engrais en solutions renfermant de l'ammoniac non combiné

LISTE n° 1 (suite)

Nom des produits

Fusées- détonateurs contenant des explosifs classe A
Grenades à main
Gaz d'hydrocarbure, liquéfié
Acide cyanhydrique, liquéfié
Acide cyanhydrique (acide prussique), liquide
Acide sulfhydrique
Isobutylene ou gaz de pétrole liquéfié
Fusées d'assistance au décollage (Jato), explosif classe A
Explosifs de faible puissance
Méthane
Géthylamine, anhydre
Gaz d'hydrocarbures non liquéfiés
Oleum
Oxygène, liquide pressurisé
Explosifs propulseurs de classe A
Liquides pyrophoriques, n.s.a.
Matières radioactive d'activité spécifique faible
Munitions pour fusées avec projectile explosif
Cyanure d'argent
Sodium métallique

Nom des produits

Cyanhydrine d'acétone
Acide picrique
Pricate d'ammonium
Munitions chimiques
Munitions pour canon avec projectiles contenant des gaz
Munitions pour canon avec projectiles incendiaire
Munitions pour arme de petit calibre avec projectile incendiaire
Cyanure de barium, solide
Poudre noire explosive
Poudre noire en pastille
Poudre noire
Assemblages d'amorces détonantes avec cordeau détonant à enveloppe métallique à charge réduite (plus de 1000)
Assemblages d'amorces détonantes avec mèche lente (plus de 1000)
Relais explosifs
Bromacetone, liquide
Cyanure de bromobenzyle, liquide
Brome
Pentafluorure de brome
Trifluorure de brome
Charges de dispersion
Phosphure de calcium
Chloracetophenone, solide, liquide ou gazeux
Chloropicrine et chlorure de méthyle en mélanges
Gaz comprimés, n.s.a.
Cyanure de cuivre
Crotonaldéhyde
Cyanures, ou mélanges de cyanures, secs
Cyanure de potassium, solide
Bromure de cyanogène
Chlorure de cyanogène contenant moins de 0.9% d'eau
Cyanogène, gazeux
Cyclopropane
Explosifs radioactifs
Ether diméthylique
Diphénylchlorarsine, solide
Diphosgène
Ethyldichloroarsine
Fluor
Tétraphosphate d'hexaéthyl et mélanges de gaz comprimés
Acide Bromhydrique
Acide Bromhydrique, anhydre
Acide Cyanhydrique en solution
Acide fluohydrique et acide sulfurique en mélanges
Bromure d'hydrogène
Hydrogène gazeux non liquéfié
Hydrogène liquéfié
Fusée d'assistance au décollage (JATO)
Chloropicrine et mélanges de gaz comprimés non inflammables et non liquéfiés

LISTE n° 2 (suite)

Nom des produits

Explosifs, classe A
Fusées d'assistance au décollage
Explosifs d'allumage
Agents irritants, n.s.a.
Cyanure de plomb
Lewisite
Gaz d'hydrocarbures liquéfiés
Gaz non inflammable liquéfiés chargés avec de l'azote, du bioxyde
de carbone ou de l'air
Explosifs de faible puissance
Chlorure mercurique
Cyanure de mercure, solide
Méthyldichlorosilane
Mercaptan méthylique
Monochloroacétone stabilisé
Gaz moutarde
Sulfonitriques, mélanges
Bioxyde d'azote
Engrais azotés en solution
Tétroxyde d'azote, liquide
Tétroxyde d'azote et acide nitrique en mélanges contenant jusqu'à
33.2% en poids de bioxyde d'azote
Nitroglycérine, esprits de
Chlorure de nitrosyle
Protoxyde d'azote
Phosphates organiques n.s.a. en mélanges avec des gaz comprimés
Pentaborane
Perchlorates, n.s.a.
Acide perchlorique en concentration ne dépassant pas 72%
Chlorure de phénylcarbylamine
Phényldichloroarsine, liquide
Phosyène
Phosphore sec, blanc ou jaune
Liquides ou gaz toxiques n.s.a.
Grenades de police, Gaz toxique classe A
Chlorure de pyrosulfuryle
Matière radioactive, articles exemptés, quantités exemptées, fissile,
forme normale
Matière radioactive, forme spéciale
Grenades à fusil
Fusées avec charge illuminante
Fusées avec charge gazeuse
Fusées avec charge incendiaire
Fusées avec charge fumigène
Moteurs pour fusées, explosifs classe A
Tétrafluorure de silicium
Hexafluorure de soufre
Anhydride sulfurique stabilisé
Chlorure de sulfuryle
Fluorure de sulfuryle

LISTE n° 2 (suite)

Nom des produits

Charges supplémentaires (explosif)
Chandelles lacrymogènes
Grenades lacrymogènes
Matières lacrymogènes sous forme liquide ou solide, n.s.a.
Pyrophosphate tétraéthylique et gaz comprimé en mélanges
Dithiophosphate tétraéthylique et gaz comprimé en mélanges
Tétrafluoroéthylène, stabilisé
Tétranitrométhane
Triméthylamine anhydre
Trinitrobenzène, mouillé (quantité inférieure à 16 onces)
Fluorure de vinyle, stabilisé
Ether méthyl vinylique, stabilisé
Bromure de xylyle
Cyanure de zinc.

Appendix 2

ECONOMICS ASSOCIATED WITH CP RAIL'S
WHEEL CONVERSION PROGRAM

Mechanical Department

Montreal, November 5, 1980

CONVERSION OF PLAIN BEARINGS TO ROLLER BEARING CARS

Assumptions and Qualifications

- The year 1979 is representative of what is expected to occur in terms of annual roller and plain bearing maintenance activity.
- Maintenance costs of plain and roller bearing wheelsets are mileage related.
- There exists an overall direct relationship between plain bearing wheelset changeouts and plain bearing maintenance activity.
- All costs are expressed in 1980 dollars.
- The purchase price of new plain and roller bearing axles and wheels has been developed by the Manager of Materials Office.
- The purchase price of new roller bearings has been developed by the Purchasing Department.
- The plain and roller bearing assembly costs and wheelset scrap prices have been developed by the Manager Disbursement Accounting.
- The plain bearing car to be converted possesses two wheelsets which are serviceable and two which require replacement. The two wheelsets requiring replacement would be subject to the scrapping rates for axles and wheelsets currently experienced at the wheel shop.

- The plain to roller bearing wheelset conversion will be performed in conjunction with a scheduled general car repair.
- The converted plain to roller bearing car is expected to continue running at a plain bearing car mileage.
- The car conversion cost reflects the cost of new roller bearing axles. Depending on the extent of a proposed plain to roller bearing axle conversion program, this car cost can be significantly reduced and consequently the DCF-IRR increased.
- The salvage values for roller bearing wheelsets and plain bearing wheelsets in the twentieth year can be safely assumed equal and therefore, have not been included in the DCF-IRR calculation.

Note: DCF - IRR = Discounted Cash Flow - Internal Rate of Return.

PLAIN BEARING CHANGEOUT COSTS

Plain Bearing Wheelset:

Material - (Stores Price - Scrap Credit)

Journal Brasses:

Material - 2 brasses/changeout

Lubricators:

Material - 2 lubricators/changeout

Rear Seals:

Material - 1.25 seals/changeout

Wedges:

Material - .76 wedges/changeout

Box Lids:

Material - .12 lids/changeout

Lid Seals:

Material - .61 lid seals/changeout

Bearing Oil:

Material - 2 gallons/changeout

Plain Bearing Wheelset Changeout Cost

- Material

- Labour - 2 manhours

Total Cost Per Changeout \$486.92

Say \$487.00

PLAIN BEARING MAINTENANCE COSTS

Journal Brasses:

Material -
Labour -

Lubricators:

Material -
Labour -

Bearing Oil -

Material -
Labour -

Train Accidents Due to Hot Boxes:

Plain Bearing

Hot Box Setouts:

Plain Bearing

Total Cost

Estimated 1979 CP Plain Bearing Miles on CP Lines

Cost Per Mile

Cost Per Car/Year \$ 265

Setout costs are developed on the basis of 2 carmen taking 5 hours to change a wheelset (2 hours travel time and an incremental 3 hours for the wheelset changeout).

ROLLER BEARING WHEELSET COSTS

Roller Bearing Changeout Costs

Roller Bearing Wheelset:

Material - (Stores Price - Scrap Credit)

Adaptors:

Material - .44 adaptors/changeout

Roller Bearing Wheelset Changeout Cost - Material

Labour - 1 manhour

Roller Bearing Maintenance Costs

Train Accidents Due to Defective Roller Bearings

Car Setouts Due to Defective Roller Bearings

Total Cost

Estimated 1979 CP Roller Bearing Miles on CP Lines

Cost per Mile

Cost Per Car/Year \$ 71.80

Fuel Reductions Resulting from Roller Bearing Wheels

Estimated 160 gallon x \$.80/gallon \$ 128.00

ROLLER BEARING CONVERSION COSTS

New Material Costs

Roller Bearing Axles
(4)

Wheel Blanks
(8 x)

Roller Bearings
(8)

Labour Cost for R.B. Wheelset Assembly

Roller Bearing Adaptors, Stop Blocks
(8 x)

Labour for Conversion

Total New Material Costs \$ 6,222.38

Reclaimed Material

Plain Bearing Wheelsets
(2)

Labour Cost for Remachining Journals
and Threads

Plain Bearing Axle
(1 x)

Labour Cost for Remachining Journal

Wheel Blank
(1 x)

Total Value of Reclaimed
Material \$(2,420.71)

Material Scrapped

Plain Bearing Axle
(1 x)

Wheel Blanks
(3 x)

Journal Brasses

Total Scrap Recoveries \$ (287.28)

Total Plain to Roller Bearing Car Conversion Costs \$ 3,514.39
\$ 3,514.00

DCF-IRR CALCULATION FOR THE CONVERSION
OF A PLAIN BEARING FREIGHT CAR TO A
ROLLER BEARING CAR

	YEAR	AMOUNT	PV FACTOR	x	TAX FACTOR	PV AFTER TAXES	
			10%		12%	10%	12%
<u>Plain Bearing Car:</u>							
Maintenance Costs	1-20	\$265	4.3235		3.7890	\$1145.73	\$1004.09
Changeout Costs	.875	487	.4815		.4779	234.49	232.74
	2.625	487	.4042		.3874	196.85	188.66
	4.375	487	.3343		.3140	162.80	152.92
	6.125	487	.2848		.2545	138.70	123.94
	7.875	487	.2391		.2063	116.44	100.47
	9.625	487	.2007		.1672	97.74	81.43
	11.375	487	.1685		.1356	82.06	66.04
	13.125	487	.1414		.1099	68.86	53.52
	14.875	487	.1187		.0891	57.81	43.39
	16.625	487	.0997		.0722	48.55	35.16
	18.375	487	.0837		.0585	40.76	28.49
						<u>\$2390.79</u>	<u>\$2110.85</u>
<u>Roller Bearing Car:</u>							
Conversion Costs	0	3514.20	.5		.5	\$1757.10	\$1757.10
Maintenance Costs	1-20	71.82	4.3235		3.7890	310.51	272.13
Changeout Costs	10	3559.68	.1935		.1600	688.80	569.55
						<u>\$2756.41</u>	<u>\$2598.78</u>
Fuel Reduction Savings	1-20	128.00	4.3235		3.7890	(553.41)	(484.99)
						<u>\$2203.00</u>	<u>\$2113.79</u>

DCF-IRR CALCULATIONS

	10%	12%
Plain Bearing	\$2390.79	\$2110.85
Roller Bearing	2203.00	2113.79
	<u>\$ 187.79</u>	<u>\$ (2.94)</u>

$$\text{DCF-IRR} = 10 + \left(\frac{187.79}{190.73} \right) \times 2 = 11.97\%$$

Appendix 3

Preliminary Assessment of the Relative Reliabilities of Roller Bearings and Friction Bearings on Railway Freight Cars.

1. Background

On April 17, 1980, Mr. R. March, Commissioner C.T.C., contacted Mr. Y. Dubé, Vice-President Research and requested that the Research Branch undertake to study the question whether railway freight car roller bearings are more reliable than friction bearings on the basis of the available statistics. The question is relevant to the Mississauga railway accident in November 1979 when a tank car of toluene on friction bearings ran a 'hot-box' and eventually derailed.

This technical paper is in response to that request and provides a preliminary assessment of the relative reliabilities of roller bearings and friction bearings based upon a comparatively simple reliability model and using information compiled by Rail Services Branch, C.T.C. Section 2 provides some basic technical material on reliability models while Section 3 presents the results of applying a simple exponential failure model to statistics regarding hot-box occurrences with roller bearings and friction bearings. Section 4 provides a discussion of the results together with some cautionary observations and indicates the need for further analysis.

2. Statistical Reliability Models

A measure of an equipment's reliability is the infrequency with which failures occur in time or with use. A failure distribution is the fundamental component of a reliability model and represents an attempt to describe mathematically the length of life of a material or a device. There are many physical causes that individually or collectively may be responsible for the failure of a device at any particular instant and it is usually not possible to isolate these physical causes and account for all of them. Therefore the choice of a failure distribution among the many competing distributions that have been proposed¹ is still an art, particularly since reliance on observed failure times to distinguish between failure distributions leads to the problem that failure distributions are importantly different in the tails where observations are sparse.

Let $f(x)$ be the probability density function of the time-to-failure random variable X then the exponential failure distribution given by

$$f(x) = \lambda e^{-\lambda x} \quad x \geq 0$$

is probably the most fundamental distribution in reliability theory. The exponential distribution corresponds to a purely random failure pattern; mathematically this means that whatever the cause of failure, it is assumed to occur according to the postulates of a Poisson process with some parameter λ .

¹ For a recent discussion of statistical failure distributions see Mann, N., Schafer, R., and Singpurwalla, N. (1974) 'Methods of Statistical Analysis of Reliability and Life Data', John Wiley and Sons, New York.

Consider a situation wherein the device under consideration is subjected to an environment which is some sort of random process. Suppose the process generates shocks and the device will fail if a shock occurs and will not fail otherwise. Interest centres on the random variable X , where X denotes the time interval between the successive occurrence of shocks, and in this situation X represents the time-to-failure of the device. To obtain the failure distribution of X we require

$$P(X \geq x) = P \left\{ \text{no shocks occur during the interval } (0, x) \right\}$$

where $x=0$ denotes the time when the most recent shock occurred. Let $P_m(x)$ be the probability that exactly m random shocks occur during a time interval of length x , then the process $\left\{ P_m(x), x \geq 0 \right\}$ is a Poisson process if it is characterized by the following two postulates:

(i) the process is time homogeneous and future occurrences of the random shocks are independent of past occurrences. Therefore the probability of a shock during $(x, x+h)$ is $\lambda h + o(h)$ where parameter λ is called the hazard rate of the process.²

² Any function $g(h)$ may be represented by $o(h)$ when h is small if

$$\lim_{h \rightarrow 0} \frac{g(h)}{h} = 0.$$

(ii) the probability of more than one event during $(x, x+h)$ is $o(h)$.

From these two postulates it follows from a familiar but technical derivation that

$$P_m(x) = \frac{(\lambda x)^m}{m!} e^{-\lambda x} \quad m = 0, 1, 2, \dots$$

Therefore by assuming that the process of random shocks is a Poisson process we have that

$$\begin{aligned} P(X \geq x) &= P \left\{ \text{no shocks occur during the interval } (0, x) \right\} \\ &= P_0(x) = e^{-\lambda x} \end{aligned}$$

Thus $P(X \leq x) = 1 - e^{-\lambda x}$ from which we immediately determine $f(x) = \lambda e^{-\lambda x}$.

The above outline of the derivation of the exponential failure distribution has been given in order to specify precisely the assumptions underlying the model; a discussion of these assumptions and their relevance to the present problem of failure of railway freight car bearings appears in Section 4.

A property of the exponential distribution which makes it especially important in reliability theory, and for this application in particular, is that the remaining life of a used device is independent of its initial age; this lack-of-memory property implies that previous use does not affect future life. Therefore, in statistical estimation of mean life, data may be collected

consisting only of the number of hours of observed life and the number of observed failures; the ages of devices under observation are irrelevant. Given the limited nature of the data currently available in this study, it is this property that primarily determined the choice of the exponential distribution as the reliability model for bearing failure.

3. Application to the Problem of Bearing Failure

A railway freight car wheel and axle assembly constitute a highly stressed mechanical system. The bearings for the assembly may be one of two principal types, roller bearings or friction bearings (alternatively called plain or solid bearings), and the housing for the bearings together with miscellaneous components which occur at each end of the axle are called journals or journal boxes. Failure of the bearings results in an overheated journal or hot-box and in Table 1 is presented a summary of the number of overheated journals and the average number of car-miles per overheated journal by type of bearing for the years 1970-1978. These statistics were compiled from information obtained by the American Association of Railroads (AAR) from its members and included in its membership are both CP and CN Rail.

Table 1: Summary of the number of overheated journals and the average number of car-miles per overheated journal for both roller bearings and friction bearings for the years 1970-1978

Year	Overheated Journals		Car-miles per Overheated Journal	
	Roller Bearings	Friction Bearings	Roller Bearings	Friction Bearings
1970	842	17,021	19,707,280	1,063,171
1971	1132	14,424	15,461,027	1,115,316
1972	1393	14,357	14,707,368	977,052
1973	1435	14,366	15,973,918	908,252
1974	1429	14,132	16,462,670	834,628
1975	1578	12,899	14,198,342	707,223
1976	1544	11,648	15,732,613	732,339
1977	1717	11,260	15,207,468	732,852
1978	1724	10,193	14,557,938	811,047

Source: Rail Services Branch, C.T.C.; compiled from the AAR quarterly hot-box and performance report form.

An examination of the number of overheated journals indicates an increasing trend in the number of roller bearing failures accompanied by a decreasing trend in the number of friction bearing failures: these trends are a result of a program of replacement of friction bearings by roller bearings over a number of years so that the percentage of AAR cars equipped with roller bearings in 1979 was 66.40% compared to 41.54% in 1971.

No trend is apparent in the average number of car-miles per overheated journal with roller bearings; the series is relatively constant over time with the exception of 1970 when the average number of car-miles per roller bearing failure was considerably larger than in subsequent years. It has been suggested that the segment of the freight car fleet equipped with roller bearings in 1970 had a higher proportion of newer cars than the segment of the freight car fleet equipped with friction bearings. As can be seen from Table 2 the gradual increase in the percentage of freight cars equipped with roller

bearings did not show any marked change just prior to 1970 which suggests that some other explanation is required and this merits further investigation.

Table 2: Summary of the percentage of freight car equipped with roller bearings for the years 1964-71

<u>Year</u>	<u>Percentage</u>	<u>Change in Percentage from Previous Year</u>
1964	11.64	
1965	15.19	+3.55
1966	20.12	+4.93
1967	24.73	+4.61
1968	28.09	+3.36
1969	32.34	+4.25
1970	36.45	+4.11
1971	41.54	+5.09

Source: Rail Services Branch, C.T.C.; compiled from AAR Yearbook of Railroad Facts 1972 and the AAR semi-annual summation of performance reports on journal roller bearings.

On the other hand there was a marked decrease in the average number of car-miles per overheated journal with friction bearings during the period 1971-75 with an overall decrease of 24% between 1970 and 1978. As an explanation for this trend it has been suggested that there has been a tendency to run the roller bearing fleet primarily on main lines with a corresponding tendency to run the friction bearing fleet on branch lines where conditions of the track are poorer. This would imply that as the percentage of freight cars equipped with friction bearings declines the proportion of the friction bearing fleet running on branch lines might increase resulting in a lower average number of car-miles per friction bearing failure. However, running on branch lines also implies axle load limits (also effective January 1, 1973 remaining friction bearings had to have the load limit reduced to 240 000 lbs. gross weight on rail) and slower speeds which might offset the effect of poorer track conditions. These conjectures also merit further investigation but information which might shed light on these issues is not currently available to the author.

In the absence of available life test data, collected under laboratory or controlled field conditions, the assessment of the relative reliabilities of roller and friction bearings will be based on operational performance statistics. Since the data presented in Table 1 provides evidence of changing circumstances over time with respect to both roller and friction bearings, but particularly with respect to friction bearings, then the assessment of relative reliabilities will be made on an individual year basis.

Let X denote the miles-to-failure of a freight car where failure represents an overheated journal bearing. We are assuming that failure is a function of use in terms of car-miles rather than time in terms of aging, and we are also assuming that all journals on a freight car are of the same type and that two or more simultaneous overheated journals on a car is an event of probability zero.

Furthermore, if we consider an exponential failure distribution for X with hazard rate λ and suppose that in any one year freight cars with one type of bearing are operating independently and move a total of N car miles with r failures then it may be shown³ that the maximum likelihood estimate $\hat{\lambda}$ is given by $\frac{r}{N}$. The inverse of the estimate of the hazard rate $\hat{\theta} = \hat{\lambda}^{-1}$ is termed the mean mileage-to-failure and it is this estimate on an annual basis that appears in Table 1 in the last two columns.

In order to compare mean mileage-to-failure estimates for roller and friction bearings and to determine whether they are significantly different, 99% confidence intervals were calculated for each of the two estimates on an

³ Ibid., pp. 180-181.

annual basis. A conservative two-sided confidence interval at level $(1-\alpha)$ is given by

$$\left(\frac{2r \hat{\theta}}{\chi^2_{2r+2, \alpha/2}}, \frac{2r \hat{\theta}}{\chi^2_{2r, 1-\alpha/2}} \right)$$

where $\chi^2_{\nu, \alpha}$ is the upper $\alpha\%$ critical value of the Chi-squared distribution with ν degrees of freedom;⁴ mean mileage-to-failure estimates and the corresponding 99% confidence intervals appear in Table 3.

It is immediately apparent that mean mileage-to-failure estimates for roller bearings are significantly larger than the mean mileage-to-failure estimates for friction bearings for each and every year. Therefore given the assumptions of the model, it is clear that roller bearings are significantly more reliable than friction bearings in terms of mean mileage-to-failure.

Assuming that on average a freight car runs 25,000 miles a year⁵ then estimates may be obtained on the survival probabilities for cars equipped with roller bearings and friction bearings. The probability of survival past distance x is given by

$$P(X \geq x) = e^{-\lambda x}$$

⁴ Ibid. p. 181. When ν is large $\chi^2_{\nu, \alpha}$ may be approximated by $\nu + Z_{\alpha} \sqrt{2\nu}$ where Z_{α} is the upper $\alpha\%$ critical value of the Normal distribution.

⁵ In 1978 total freight car-miles was 4,720,487,663 for Canadian railroads and the number of freight cars in service (excluding privately owned cars) was 182,138 giving an average annual mileage of 25,917 miles. Source: Statistics Canada 52-207, 'Railway Transport, Part 1' 1978.

Table 3: Mean Mileage-to-failure estimates for roller and friction bearings for the years 1970-78 together with corresponding 99% confidence limits

Year	Mean Mileage-to-failure in millions $\hat{\theta}$		99% Confidence Interval		Mean Mileage-to-Failure in millions $\hat{\theta}$		99% Confidence Interval	
	Roller Bearings	Lower Limit	Upper limit	Friction Bearings	Lower Limit	Upper Limit		
1970	19.707	18.080	21.627	1.063	1.043	1.085		
1971	15.461	14.349	16.743	1.115	1.092	1.140		
1972	14.707	13.748	15.798	0.977	0.956	0.999		
1973	15.974	14.947	17.139	0.908	0.889	0.928		
1974	16.463	15.402	17.666	0.835	0.817	0.853		
1975	14.198	13.326	15.183	0.707	0.691	0.724		
1976	15.733	14.755	16.836	0.732	0.715	0.750		
1977	15.207	14.309	16.215	0.733	0.715	0.751		
1978	14.558	13.700	15.521	0.811	0.791	0.832		

and so in 1978 the survival probability past 25,000 miles for a freight car equipped with roller bearings was $0.998 = e^{(-25,000/14,557,938)}$ and for a freight car equipped with friction bearings was $0.970 = e^{(-25,000/811,047)}$. Therefore, given the assumptions of the model, the use of roller bearings instead of friction bearings increases the survival probability of an average freight car by approximately 2.8%.

4. Summary

The key in assessing the conclusions drawn in Section 3 is the reliability model used in the analysis and its relevance to the causes of freight car bearing failure. In particular, the relative importance of random shocks, such as loading impacts or steps in the truck due to the truck being out of alignment, compared to general wearing is crucial. Examination of an AAR quarterly hot-box and performance report for the third quarter of 1979 indicates that 64.4% of roller bearing failures and 27.7% of friction bearing failures were due to undetermined or unspecified causes. Therefore while random shocks may constitute a significant contributing factor to bearing failure it is to be expected that general wearing will also play an important part.

If wearing is a contributing factor then previous use will indeed affect future life and the failure generating process cannot be time homogeneous; therefore the lack-of-memory property of the exponential failure distribution is violated. This lack-of-memory property of the exponential distribution results in the constant hazard rate and instead a more general family of

failure distributions with variable hazard rate curves, such as the Weibull distribution, might be a more appropriate reliability model.⁶ However with the limited operational performance data available, and in the absence of life test data from laboratory or controlled field experiments, the parameters of a reliability model using the Weibull failure distribution cannot be estimated.

Therefore since the reliability model used in this analysis has its limitations a certain caution must be exercised when considering the results and the need for further investigation is indicated.

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⁶ For an application of the Weibull distribution to ball-bearing failures see Lieblein J. and Zelen M. (1956) 'Statistical Investigation of the fatigue life of deep-groove ball bearings' Journal of Research, National Bureau of Standards, Vol. 57, pp. 273-316.

